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Numerical Simulations of the NetLander Ionosphere and Geodesy Experiment (NEIGE): Landing Site Positions Determination From Doppler Tracking Between an Orbiter and Landers

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Introduction: The NEIGE experiment, foreseen to be part of the NetLander mission, will allow modeling both the internal structure of Mars (non rigid versus rigid nutations) and the balance of volatiles (seasonal C02 mass exchanges at polar caps). Along with Mars' orbiter tracking from the Earth, this experiment consists in analyzing the radio Doppler shifts between this orbiter and four landers on Mars' surface, to monitor the fine fluctuations in the motion of its rotation axis. However, the entry descent-landing phase will induce relative large uncertainties on landing site locations, thus implying an accurate estimate of Lander positions with respect to the small motions to be detected (a few centimeters at Mars' surface)

Numerical simulations: An orbiter with a network of four Landers on Mars' surface (three separated each other by a few 1000 Km and one at antipodal location) is chosen for the simulation. A near-polar orbit at an altitude of 500 Km is considered. We use the "GINS" orbitography software, developed at GRGS/CNES (Toulouse, France), which numerically integrates the spacecraft Cartesian state and force model the partial derivates. We assume that the forces acting on the spacecraft are perfectly known, implying a very accurate orbit determination. We also model the fine perturbations of Mars' rotation, by introducing 12 parameters. Ten represent the Polar motion and the length-of-day (LOD) variations and correspond to amplitudes of trigonometric series with mainly annual and semi-annual periods (Yoder and Standish 1997, Van den Acker et al., 2002). The two last ("non-rigid" parameters) represent the effect of a possible liquid core on the nutations of the planet. Their values primarily depend on the core size and flattening (Folkner et al., 1997). Based on initial values of these rotation parameters and of the Lander positions, we have simulated Doppler data (UHF/S-band link) between the orbiter and the Landers and Deep Space Network Doppler tracking (two-way X-band link) of this orbiter from the Earth, both with an instrumental noise of 0.1 mm/s. Then, through a least squares adjustment from these signals, we have tried to retrieve the rotation parameters and Lander positions, given a priori values different from the initial ones. This simulation approach permits to analyze the precision on the Landers positions determination and on the rotation parameters retrieval.

Results: Depending on the technical solutions adopted for the entry-descent landing phase, uncertainties on the Landers positions can correspond to error ellipse of 250 Km x 50 Km (worst case) on the surface of Mars. We introduce such errors as the difference between initial and a priori values in our simulation. We only select one pass (about 15 minutes) of the orbiter over each Lander per week to take into account the Lander' power supply limitations. In a first step, we only adjust Lander positions without adjusting the rotation parameters (with a priori values slightly different from the initial ones). We find that only 5 weeks of data are needed to retrieve Lander positions with a precision of a few meters. This expresses the difference between a priori and initial values of the rotation parameters, especially the LOD variations that induce a displacement of the Lander's longitude of about 9 meters at the equator. Then, we start from these positions estimates to adjust both Lander positions and rotation parameters over half a Martian year. We find a final precision of a few centimeters on the Lander location at Mars' surface and of a few milli-arc seconds for the LOD variations and Polar motion amplitudes and less than 20% on the "non-rigid" nutation parameters, thus reaching the scientific objectives of the NEIGE experiment. Future simulations will consider a higher Doppler noise, time biases foreseen on the NEIGE Doppler data (due to orbiter onboard clock drift) and orbit perturbations like those induced by the spacecraft angular momentum desaturations. Our simulation can also be applied to others planetary missions using an orbiter/Lander Doppler radio link.

References:

Folkner et al. 1997, JGR, 102, pp. 4057
Van den Acker et al., 2002, JGR, 107, pp. 1029
Yoder and Standish, 1997, JGR, 102, pp. 4065.